RESEARCH DEPARTMENT

A digital terrain coder for transferring map data onto paper tape

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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It uses SI units in accordance with B.S. document PD 5686.

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SUMMARY

A description is given of equipment used to prepare the main input data for predicting the service area of u.h.f. transmitters by computer. Information on contour height and other topographical features as a function of bearing and distance from the transmitter, obtained from Ordnance Survey maps, is coded and punched onto a paper tape. This can be done directly by an operator who is well versed in map reading but need not have any other special training.

1. GENERAL

When the service area of a u.h.f. transmitter is calculated, a large amount of data on the topography of the area is required. In the past this has been abstracted from maps, written down, and then transcribed onto paper tape for feeding into a computer.[1] This is a slow laborious process and is liable to error in one or other of the stages. Equipment has therefore been developed in order to shorten this process and reduce errors.

In practice, a map of the area surrounding a proposed transmitter site is sampled by a number of radials. Each of these is traversed by a mechanically driven cursor shown in Fig. 1. As the cursor moves along the radial, the distance from the site is automatically registered while other data are coded (as described in more detail in Section 2) and transferred onto paper tape by operation of the appropriate switches.

The equipment is intended for use with either 1 in. to the mile (1/63,360) or 2½ in. to the mile (1/25,000) Ordnance Survey maps which have contours in steps of 50 ft (15 m) and 25 ft (7·5 m) respectively. The height may be indicated in steps of 5 ft (1·5 m) up to a maximum of 4995 ft (1·5 km). Other distance scales can be accommodated by using different computer programmes for the calculations.

Fig. 1 - Photograph of complete equipment

2. OPERATION

Before using the equipment, the map has to be annotated with the required radials and other necessary data. The sequence of operation for transferring the data from each radial onto punched tape is arranged to fit in with the computer programme. For the currently used programme the sequence of data on the tape is as follows:

(i) A length of blank tape on which reference data (name of transmitter site etc.) can be written manually.

(ii) The bearing of the radial.

(iii) Instructions on the points and intervals along the radial at which calculations of field strength are to be made by the computer.

(iv) Height and distance information.

(v) Density coding to indicate the type of terrain, i.e. houses, woods, orchards etc.

Some of these items are explained in more detail below; for this purpose it is convenient to adopt a different order from that of the programme. The details of the punched-tape codes are indicated in Fig. 2.

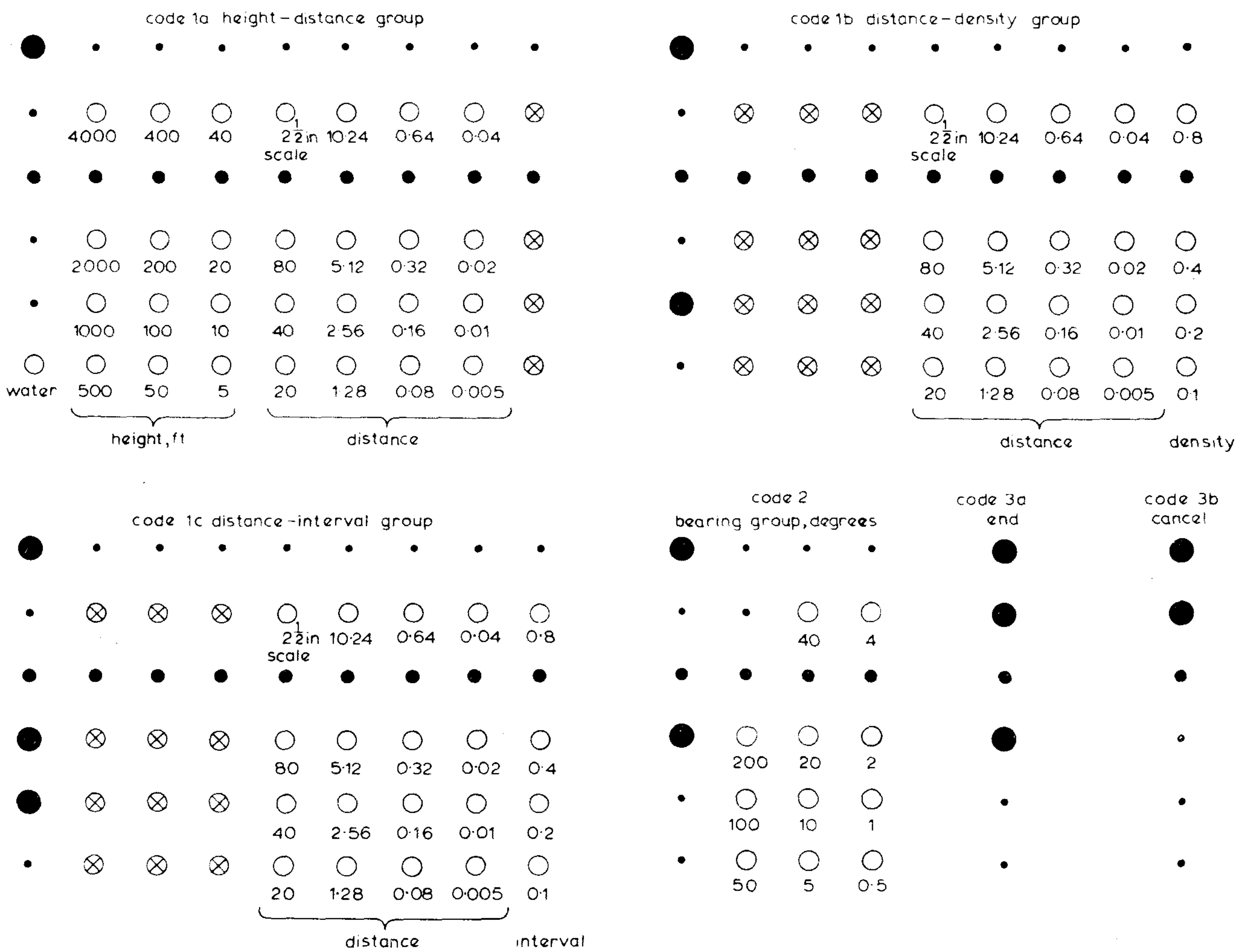

Fig. 2 - Tape codes

Must be punched — Punched according to data
Feed hole — Not punched
May be punched, but data not used in present programme

Values are as shown when holes punched, except
Scale: 1 in. when not punched
Water: Land when not punched

Note: Distance values in inches on map

2.1. Height

The coding of the height information is the most important item since this, as a function of distance along the radial, gives the ground profile. The operation is facilitated in practice by keys which increase or decrease the height in the register (as shown on the display) by one contour interval. Thus, having set the initial height, further entries normally take place each time the cursor crosses a contour as it is moved along the radial, the new height being set by one operation of the UP or DOWN key. The numerical display provided in the equipment acts primarily as a guide to the operator by giving a continuous check of the height information, although it is also used when entering the bearing onto the punched tape as explained later. When the PUNCH key is operated the height information is punched as a sequence of pairs of numbers according to code 1(a) in Fig. 2, the first giving the height and the second the corresponding distance. The distance information is derived automatically from the cursor position.

The computer programme calls for a parabolic interpolation between three consecutive heights when determining the height of any given point on the radial. As this would obviously be wrong if two heights involved stretches of water a special key switch is provided to indicate the presence of water, and the computer can take this into account. The first column of the data group conveys this land/water information.

2.2. Density

The next code in order of importance, is the 'density' which indicates the type of terrain. This is read off the map during a separate run of the cursor along the radial. For this operation, keys are used for the coding and provision is made for up to eleven types of topography to be recorded using code 1(b) of Fig. 2.

2.3. Interval

A further run is made over each radial to indicate the position and intervals at which calculations of field strength are to be made by the computer. In general, more points have to be calculated in built-up areas than in the open country. Coding is again carried out by the operation of switch keys and is shown as code 1(c) of Fig. 2.

2.4. Bearing

The bearing of the radial is coded by setting the appropriate switch to BEARING and using the height/bearing switches to give the required bearing to the nearest 0·5° on the display. Operation of the PUNCH key transfers the bearing onto the paper tape according to code 2 of Fig. 2.

2.5. Miscellaneous

On completion of a radial, the END button is operated to indicate to the computer that the radial has been completed.

If at any time an error is made then the last group punched may be cancelled by operating the CANCEL button. This may be repeated any number of times but the computer programme is such that it will not cancel beyond the first of a series of similar groups e.g. height-distance group. These two codes are shown in Fig. 2 as codes 3(a) and 3(b) respectively.

3. EQUIPMENT DESCRIPTION

The complete equipment as shown in the photograph of Fig. 1 comprises:

(a) the main unit
(b) the cursor unit
(c) the control unit
and (d) the tape puncher

All controls are on the main unit with the exception of the PUNCH switch, the cursor motor LEFT-RIGHT switch and the height UP-DOWN switches which are on the control unit.

For descriptive purposes the first three units will be taken together but will be sub-divided into the cursor motor drive, the distance counter, the height counter, the punch sequence control and the power supplies.

3.1. The Cursor Motor Drive

A block diagram of the cursor motor drive is shown in Fig. 3.

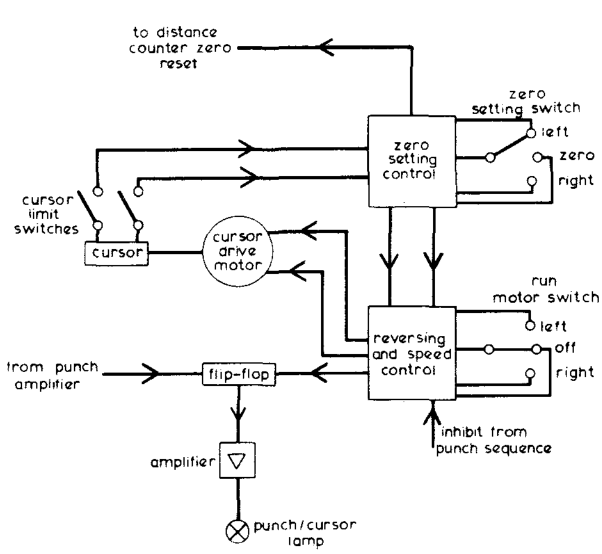

Fig. 3 - Motor control block diagram

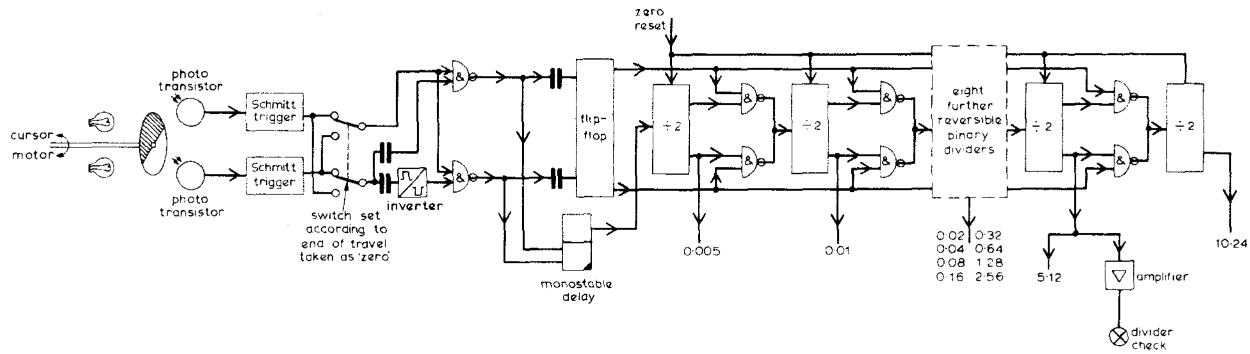

Fig. 4 - Distance counter block diagram

The cursor motor is a d.c. permanent-magnet motor which obtains its power from an emitter-follower power amplifier. The three-position operating key has a LEFT or RIGHT position for moving the cursor in either direction. When the key is released it returns to the centre position and the motor is short-circuited, giving very fast braking. A large capacitor across the input to the emitter follower charges slowly from 3V to 10V on operating the motor key. This gives a slow start to the motor which gradually accelerates as greater movements are required. For the return to zero the cursor is driven at maximum speed with 13V across the motor. This is accomplished by a special key, which also ensures that the distance counter starts at zero.

The motor drives the cursor via a gear train and twin leadscrews. Either of the end positions can be used as the ZERO starting position. Limit switches are provided at either end to prevent the cursor being over-driven.

As a general check on sequence of operations, a flip-flop operating a lamp is provided. This lamp is switched on when the punch operates, and off when the cursor is moved.

3.2. The Distance Counter

A block diagram of the distance counter is given in Fig. 4.

The distance counter uses a reversible 12-bit binary counter driven from a rotation detector. This consists of a clear plastic disc, blacked out over a 180° arc, mounted on the motor shaft. It rotates between a pair of photo-transistors and their associated lamps which are so mounted that one operates at approximately a quarter of a turn of the disc after the other. The outputs of the photo-transistors operate a pair of Schmitt trigger circuits followed by logic circuits which determine the direction of rotation and set the counter chain for addition or subtraction. By this means the counter is able to keep a continuous log of the position of the cursor, bearing in mind that the counter is automatically set to zero when the cursor is zeroed.

The method of achieving a reversal of the direction of count is to select, by means of gates, which side of each binary stage should provide the trigger 'carry one' pulse for the next stage. To provide a check on the operation of the counter, the last-but-one divider stage is arranged to control an indicator lamp. Each binary stage controls a gate of the main output selection circuit which comes into play when information is punched.

The smallest distance recorded is 0·005 in. (0·127 mm) of cursor movement, and a total cursor movement of just over 20 in. (500 mm) is permitted. Key switches which directly operate the main selection gates provide for zero offsets in steps of 20 in. (500 mm) up to 140 in. (3·5 m).

3.3. The Height Counter

A block diagram of the height counter is given in Fig. 5.

The counter unit counts up to 4950 or 4975 in steps of either 50 or 25, the step size being selected by the CONTOUR switch. It is not reversible in the normal sense, but counting down is achieved by a special system described later. Since a numerical display of the count is required it is convenient to use a decade rather than a binary counter. The inputs to the counter are from UP and DOWN switches mounted on the control unit. For this purpose the switch outputs are converted to standard pulses by monostable circuits. If the CONTOUR key is in the 50 ft. position then the UP switch pulse is inverted and differentiated to give a second pulse into the counter, each pulse giving a 25 ft. step. The first stage of the counter is a bistable divide-by-two circuit which drives two cascaded decade divider stages. Each of these decade stages consists of a binary counter followed by three binary stages with feedback to reduce the division ratio from eight to five. The four binary-coded decimal outputs from each decade counter supply individual gates in the main sequence output circuits.

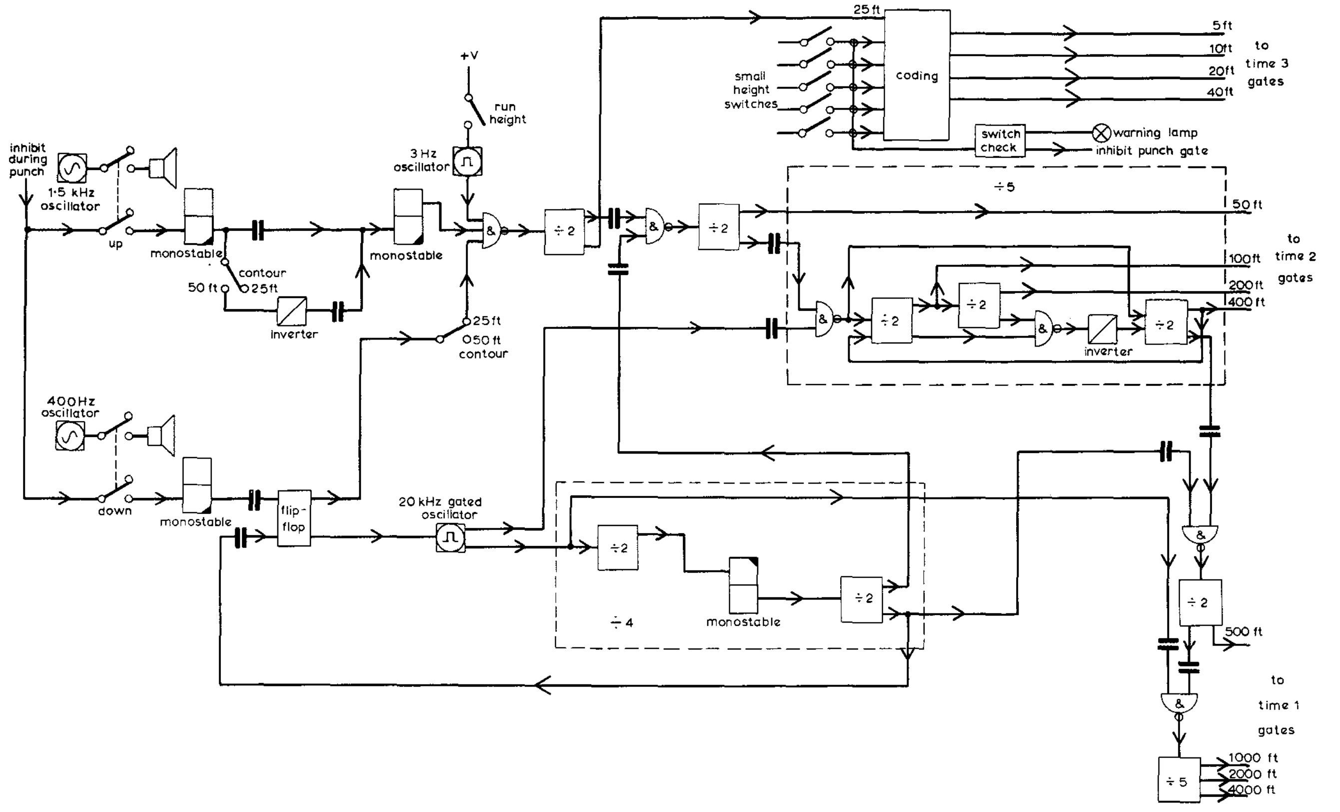

Fig. 5 - Height counter block diagram

The output from the first divider (25 ft) operates a coding circuit. This can include small-height adjustments provided by the SMALL-HEIGHT keys to give outputs in 5 ft. steps. If two or more SMALL-HEIGHT keys are operated, simple summing amplifiers block the punch and bring on a red warning light. The voltage outputs from each decade (including small heights) also supply resistors, the values of which increase in binary progression so that the combined current is proportional to the decade count. These currents operate 'Digivistors', commercial devices consisting of a meter movement and an optical system which projects numbers proportional to the current through the movement and hence to the decade count, onto a screen.

When the counter is required to step down, use is made of the fact that on the final stage of the counter there is no carry to a higher order and in consequence the addition of 4950 ft (or 4975 ft for 25 ft contours) is equivalent to the subtraction of 50 ft (or 25 ft). This is carried out in the following manner.

The DOWN switch initiates a sequence in which pulses from the 20 kHz gated oscillator are used to trigger the height counter four times at the 1000 ft and 100 ft stages and (using the divide-by-four stage) once at the 500 ft and 50 ft stages thus totalling 4950 ft. For 25 ft contours, an addition of 25 ft is also made via a contact on the CONTOUR key.

At the start of a run along a radial it is often necessary to change the height-counter reading through a large part of its total range, particularly during and after the setting of the bearing. To simplify this a 3 Hz oscillator supplies pulses to the first stage of the height counter when the RUN HEIGHT key is operated, thus enabling the height counter to be quickly set to the approximate value.

When either the UP or DOWN switches are operated aural indication is given to the operator that the correct switch has been depressed without the need to look at the height at every step. This consists of a high or low tone, each produced by an oscillator feeding a small loudspeaker.

The height counter is also used for setting bearings without any changes to the counter itself. When the BEARING key is depressed a decimal point appears on the height display allowing the bearing of the radial to be set on the HEIGHT keys to the nearest 0·5°. Operation of the PUNCH key transfers the data onto the paper tape.

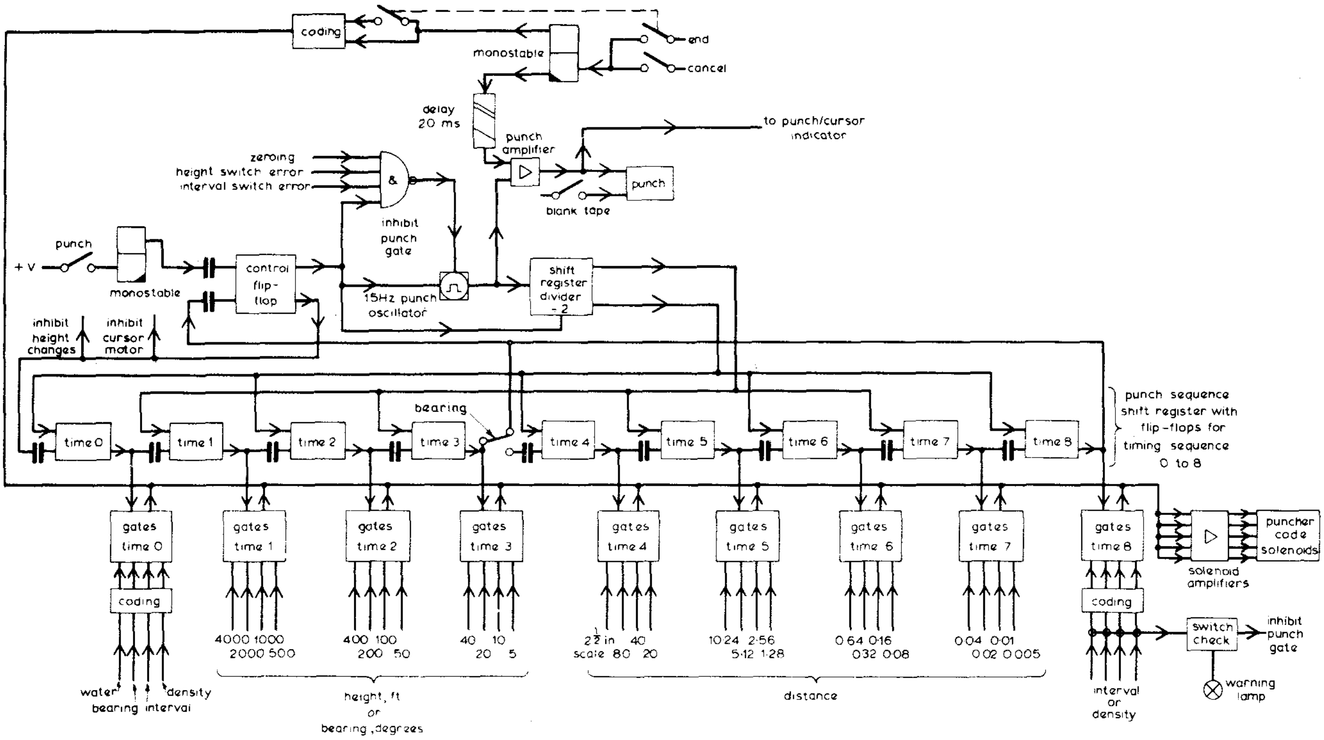

Fig. 6 - Punch sequence block diagram

3.4. Punch Sequence Control

A block diagram of the punch sequence control is shown in Fig. 6. There are four controls which cause tape to be punched – the BLANK key, the CANCEL key, the END key, and the PUNCH switch. The BLANK key, by direct switching, causes blank tape to be run out as long as the key is depressed. The CANCEL and END keys put a simple code onto the tape. Operation of either of these keys triggers a monostable which operates the appropriate code solenoid amplifiers to set the required punches. The output of the monostable also operates the punch solenoid after a 20 ms delay provided by a simple RC network on the input of the punch amplifier.

When the PUNCH switch is operated a monostable sets a control flip-flop which starts the data punching sequence. The flip-flop output removes any drive to the cursor motor and renders the HEIGHT switches inoperative. It also removes the clamp from the 15 Hz square-wave oscillator and triggers the punch sequence shift register. Providing that the oscillator is not blocked by incorrect switch settings or a zeroing operation it will supply, alternately, negative pulses to the shift register divider and positive pulses to the punch amplifier.

The timing of the punching operations is controlled by a chain of nine flip-flops forming the shift register. These are fed from the shift register binary divider so that antiphase shift pulses are passed to alternate stages of the chain. This system acts as an electronic escapement and ensures the correct progress of the triggering pulse from one stage to the next. On receipt of the pulse from the control flip-flop, the first of the shift register flip-flops changes state and enables the time 0 gates to conduct. Whether or not these gates will conduct depends on the settings of the WATER, BEARING, INTERVAL and DENSITY switches. Any of these gates that are conducting will provide inputs to the code solenoid amplifiers ready for the punching operation which occurs during the second half-cycle of the punch oscillator. At the end of the second half-cycle the first shift register flip-flop will be reset by the shift register divider and will trigger the second flip-flop. This will enable the time 1 gates to operate and pass information from the first group of height counters. At the end of the second complete oscillator cycle, after punching these values, the second shift register flip-flop will reset and trigger the next stage.

This process will be repeated down the full length of the chain until the last stage is reached when the resetting will turn off the control flip-flop and stop the punch oscillator. This will also reset the shift register divider. When a bearing is being punched the time 3 stage of the shift register

terminates the punching sequence. Provision is made to clear the shift register automatically on switching on and thus prevent irregular operation of this circuit.

If two or more HEIGHT or DENSITY keys are operated, an incorrect condition, simple summing amplifiers block the punch and bring on red warning lights.

3.5. Power Supply Unit

The power supply unit has three d.c. outputs: an unstabilized 50V output to operate the motor and punch solenoids, an unstabilized 12V supply to operate warning and photo-transistor lamps and relays, and a stabilized 4V supply for the remainder of the equipment. The 4V supply is provided with an overcurrent limiter. The projection lamps in the Digivistors are run off a 6·3V supply as is the decimal point lamp used when the BEARING key is operated.

3.6. The Puncher

The puncher is a commercial high-speed tape puncher, Creed model 25 H.S.

4. CONCLUSIONS

In operation this machine saves a very considerable amount of time in the preparation of data for the computer calculation of the service areas of u.h.f. transmitters.

It has been found that the time taken to record on tape a 10 mile (16 km) radial from a 1/25,000 map already marked up with the radial and other necessary data is reduced from about two hours to less than one. The time to check and correct the tape has also been considerably reduced, mainly because of a considerable reduction in errors. Since, for a typical transmitter, at least thirty radials must be processed, the total saving of time is quite considerable.

5. REFERENCE

1. Computer method of service area prediction at u.h.f. BBC Research Department Technical Memorandum No. RA-1010, August 1967.

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